CHAPTER 1
SUMMARY OF THE FLIGHT TECHNOLOGY IMPROVEMENT WORKSHOP

INTRODUCTION

The Flight Technology Improvement Workshop, sponsored jointly by the Office of Aeronautics and Space Technology and the Office of Space and Terrestrial Applications of NASA Headquarters and the Langley Research Center, was held at the University of Maryland's Center of Adult Education in College Park, Maryland, July 31 to August 2, 1979.

The purpose of the workshop was to bring together space instrumentation technologists from government and industry in order to discuss past spaceborne instrument deficiencies and shortcomings and to recommend potential corrections and technology developments to offset the occurrence of such problems in the future. Approximately 80 individuals participated in the workshop - 27 from industry and the balance from the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Bureau of Standards, and the Department of Defense (Space and Missile System Organization and Naval Research Laboratory).

The workshop was organized into four panels covering specific problem areas: Optical Radiometric Instrumentation and Calibration, Electromechanical Subsystems, Attitude Control and Determination, and Power Subsystems. A series of technology recommendations for near-term consideration was developed by the panels and is contained in this document.

SUMMARY OF PANEL FINDINGS

This summary covers the highlights of the recommendations by the four panels of the Flight Technology Improvement Workshop. All of the recommendations fell into three general categories:

1) Policy changes needed to facilitate the use of improved or newly developed technology.
2) Development of new devices or techniques to meet new requirements.
3) Needed improvement or use of existing technology.

Reports of the individual panels, in considerably more detail, follow this summary. It should be recognized that each panel was asked at the beginning

of the workshop to restrict their recommendations to only those items that they felt were of the most urgent nature to carry out the spacecraft programs being considered for the reasonably near future. Because of the request, it should be recognized that, even though recommendations are given in priority order, those at the bottom of the priority list are still important for successful completion of missions in the near future.

There were far more recommendations for technology improvements brought up by the members of the various Panels than could possibly be included in a report of this nature. The Panels themselves considered all of the recommendations, and selected only those they considered to be the most important to appear in the report. The practical limits of resources in manpower and funding were considered by all of the Panels in making the reports, and it is hoped that readers of this report will recognize that there are many other technical improvements that are, perhaps, needed or at least highly desirable, but that a shopping list of all technical improvements fitting those categories would be beyond the scope of the Panels' activities and would weaken the impact of this report by covering too many areas in too little detail.

Optical Radiometric Instruments and Calibration Panel Summary

The Optical Radiometric Instruments and Calibration Panel recognized that the present knowledge of in-orbit radiometric accuracy of sensors now in flight, or being prepared for flight, is poor, especially in view of requirements for monitoring of long-term changes in such areas as the measurement of the ozone concentration and in climate studies. In such areas, requirements for calibration and precision over long periods of time are found to exceed the state-of-the-art for radiometric components such as detectors, and for the calibration sources and transfer standards needed to calibrate new instruments.

In the area of improvement of existing technology, it was recognized that, although adequate standards exist at the National Bureau of Standards (NBS) for calibration of certain types of instruments, these standards are, in essence, point sources and are not appropriate for the calibration of the type of instruments planned now for the space program such as the ERBE instrument for the TIROS-N series, the Thematic Mapper for Landsat, the AVHRR (also for TIROS-N), and the SBUV that will fly on one of the NOAA satellites in the TIROS-N series. The Panel recommended that, in order to meet the requirements of long-term monitoring, new improved calibration standards are needed and the techniques for transferring the calibration to the spaceflight instruments will have to be developed. The NBS personnel participating on the Panel pointed out that the situation is particularly bad between .16 and 5 micrometers where reflectance of solar energy is the principal quantity measured. They also pointed out that it may be impossible to develop light sources themselves which are stable enough over that period of time necessary for the monitoring to be accomplished, but they felt that techniques such as reliance on very stable detectors, especially those of the silicon family, together with the improvement of sources, could provide the necessary radiometric accuracy over the periods of time needed. The NBS people felt that, with

the proper support, they could serve as the keeper of the standards against which the radiometric measurements would be checked over the long period of time in order to determine if there were changes in such things as the ozone layer concentration and the albedo of the Earth.

The devices needed for calibration, both light sources and detectors, were felt to be principally improvements of existing technology. However, in the area of techniques, the Panel recognized that the NBS had little or no contact with the space program in developing mechanisms for transferring calibration from their sources which are essentially point sources to the instruments planned for flight in the space program. They propose that, as part of the Self-Study Manual on Radiometric Calibration that is prepared and distributed by the NBS, they, together with scientists from government installations, would devise standard techniques for transfer of calibration and publish these techniques as a part of the Self-Study Manual. These volumes of the Manual will then serve as a guide to assure that calibration is done in a uniform manner, regardless of what organization carries out the calibration.

It was recognized that development of long-term stable light sources for use as on-board calibration sources was an area where new technology should be developed, since all of the sources now in use are simply commercial light bulbs designed for some other purpose and adapted to the space program. The Panel also felt that emphasis should be placed on the development of optical components with long-term stability in the space environment but that some attempts to carry out such improvements had met with difficulty. In particular, a problem was noted with super-polished optics that had been developed to reduce scattering from the optical surfaces so as to minimize contamination of the signal by scattering. After development of the super-polished surfaces, it was found that a "blue haze" developed on them. The effect of and possible methods for prevention of the "blue haze" have not been determined, and study is needed in areas such as this where newly developed optical components present previously unnoticed problems.

The Panel identified two principal areas regarding policy change: First, the Panel felt that NASA should establish calibration facilities at those NASA centers that are required to carry out calibration of radiometric sensors, and that these calibration facilities should be standardized to the highest degree possible, both in equipment and techniques. In addition, it was felt that the NBS should serve as a consultant to advise on techniques and should also carry out checks of calibration sources at the various NASA centers. The Panel supported the concept of a highly stable instrument that would be developed by the NBS, and then carried to the various calibration laboratories at NASA centers to check calibration. The NBS personnel agreed that they would undertake such an activity if they were supported. In order to coordinate the requirements, for the establishment of facilities and the standardization of equipment and capabilities, the Panel identified the need for an Interagency/Intercenter Steering Group of NASA-NBS personnel covering the total range of measurement requirements.

The second area of policy change recommended was the establishment of a Solar Test Facility to be used by all NASA centers in light of the fact that

it has been impossible to produce a source in the laboratory that simulates the Sun in intensity and spectral distribution. It was recommended that the existing NASA facility at Table Mountain in California be improved to include a tracker-mounted vacuum system so that instruments that must operate in vacuum could be used there.

One potential problem area that did not fit into any of the three categories, but was recognized as a serious difficulty for future experiments, was the contamination potential for instruments to be carried on the Shuttle. Reports of the amounts and types of materials to be dumped daily from the Shuttle indicate a serious problem with any radiometric sensor unless that sensor is protected during its entire time on the Shuttle, and then separated from the Shuttle under free flight. A complete set of specifications of materials and quantities to be dumped from the Shuttle was not available for the Panel, and they felt that such a specification should be produced or made available as soon as possible to evaluate this problem.

Electromechanical Subsystems Panel Summary

The Electromechanical Subsystems Panel recommended two major areas of improvements for use of existing space technology. A major recommendation was to utilize magnetic bearings that have already been developed in a flight test for either a scanner mirror or a nutation damper. The Panel felt that the magnetic bearings have been developed to the point where they are ready for spaceflight, but they have not been used because of institutional inertia rather than any technical problem.

Also, under the area of improvements and use of existing technology, the Panel felt that a comparative evaluation is needed of signal and power transfer devices for use in space. Low noise, high reliability devices are needed to transfer signals through rotating components and, in light of the Seasat experience, some improvement is certainly necessary in the area of transferring power through rotating components.

Under the area of development of new technology, the Electromechanical Subsystems Panel recommended several new developments. Recognizing that magnetic bearings could not be the answer to all problems, they recommended that devices be developed to force-feed lubricate bearings in space, and that sensors be developed to determine the need for such lubrication. Present sensors, such as microphonic devices or temperature sensing devices, are inadequate since the bearing will have been damaged beyond salvation by the time these devices indicate that lubrication is necessary.

In the area of servo devices, the Panel recommended that magnetic suspension be utilized to achieve accuracies of less than one arc second for scan-to-ray encoders. This is somewhat akin to the utilization of magnetic bearings, but is a new use of that technology in the area of servo encoders.

Another new technology area necessitated by the probability of recovery of spacecraft by the Shuttle is the development of the universal deployment

and the retraction mechanism for use with larger arrays. A number of deployment mechanisms have been devised for deploying larger arrays; however, none have ever been required to retract those arrays as will be required if a device is to be captured by the Shuttle and brought back to Earth. In light of the large number of sizeable devices that will be deployed from Shuttle-launched spacecraft, the Panel felt that it would be economical and feasible to develop a universal deployment mechanism.

Another area that the Electromechanical Subsystems Panel recommended for development and test was that of cryogenic devices. A number of new experiments planned for Shuttle launch and operational use in the 1980's will require operation at cryogenic temperatures. Devices are needed to produce such temperatures for long periods of time such as those used on operational satellites. Technology is needed in several areas such as superconducting motors, control devices, and actuators. Suspension devices and thermal switches have not yet been developed. If experiments at cryogenic temperatures are to be continued, these developments are urgently needed.

Power Subsystems Panel Summary

Under the area of new technology developments, the Power Subsystems Panel recommended several areas of critical importance. The first area dealt with AC modeling of components for use in spacecraft power systems. They emphasized that, although some data is available on the AC performance of individual components, it is completely inadequate. Furthermore, there is very little data available on the performance of systems, and that such a system study is necessary in order to improve reliability in future spacecraft power systems.

Also, under new technology, the Power Subsystems Panel noted that new diagnostic devices are needed to determine the health of the power systems on spacecraft. Such devices are discussed in detail in their report, and include such things as devices to measure the depth of discharge of batteries.

It was noted that the requirements for increasing power on new and larger spacecraft are incompatible with the present 28 volt bus system now in use. If spacecraft power is to be increased, spacecraft power busses will have to increase in voltages to the range of 150, 300, and 500 volts. The Panel noted that there are no space-qualified components available such as capacitors, semi-conductors, switches, and relays in those voltage ranges. To raise the total spacecraft power without raising the bus voltage would give rise to unacceptable current requirements on the spacecraft power system.

Another area where new technology was considered necessary was in the area of high voltages (those exceeding 1000 volts). In this area, there have been a considerable number of failures and the Panel felt that, not only is new component design necessary, but a Design Guide Handbook, including screening and testing technique specification, is necessary to eliminate repetition of the same errors by different users of high voltages on spacecraft.

Under the area of improvement of existing technology, the Panel felt that vastly improved on-board monitoring of power systems, including mechanisms to automatically protect power systems when not in view of tracking stations, is necessary in order to increase reliability. These systems would automatically carry out emergency bypass or shutdown procedures to protect the spacecraft in the event of a failure in the power system when not being monitored by a ground control station.

It was also noted by the Power Subsystems Panel that solar cell contacts and interconnections between solar cells on spacecraft have not been as reliable as desired and that with the probability of much larger solar arrays, new methods for testing the integrity of interconnections are needed and should be developed before such arrays are launched.

Nickel-cadmium batteries have proven to be inconsistent in their performance in space and, since we will apparently be relying on such batteries for long periods of time, the Panel felt that improvement in the quality of these batteries is necessary. They suspect that problems are due to processing and processing control, and feel that improvement is necessary in both of those areas to improve the reliability of nickel-cadmium batteries.

Another problem identified was the effect of the charge buildup on spacecraft due to the substorm plasma and the necessity to understand the energy profile, and how the charge will be dissipated in spacecraft systems. Studies in this area are already underway at NASA Lewis Research Center and the Panel recommended that they be continued so that failures due to substorm plasma effects can be eliminated from future spacecraft.

Attitude Control and Determination Panel Summary

The Attitude Control and Determination Panel recommended several areas under the heading of new technology. The first area is the development of control instrumentation for on-board diagnostics and self-testing instruments for improved structural positioning and rate sensing determination. They also identified large momentum exchange devices as an area in which new technology will be required in a larger spacecraft in the future. Scaling of the presently used devices up to a larger size will carry high penalties. Without such technology, in the fairly near future, such devices could become pacing items in the launch of a larger spacecraft.

Another new technology area identified is that of automated rendezvous and docking. This technology will be necessary to carry out such operations as unmanned logistics supply, planetary sample return, asteroid capture, and assemblies of structures in space. It should be noted that this automatic rendezvous and docking does not carry with it the complexity of that involved with manned rendezvous and docking since there is not a need for a pressure-tight seal or container through which men can move. Docking may be carried out by such a simple device as magnetically coupling one structure to another; but in any event, such techniques will be necessary for missions of the type mentioned above.

In the area of technology improvement, the Attitude Control and Determination Panel recommended improvement of techniques for integrating of the control, the structure, and the dynamic design of spacecraft, especially for large space structures. This is necessary since a control or attitude determination device on one part of a large space structure may not be valid for another part due to flexure between the various components of a large space structure.

They also recommended the improvement of high performance, moderate cost and long life attitude and rate sensors. This area includes solid state star trackers to replace the presently used image dissector tubes. The solid state star tracker would provide much better reliability than the image dissector which requires high voltage for operation, and would provide accuracies to sub-arc seconds that are not achievable with the present image dissector devices.

They also recommended, under the category of improvements, assessments of non-conventional gyroscopes that have already been developed for other purposes as having potential for spaceflight use. This area could also be included under Recommendation and Policy Change, since it appears that further funding will not significantly advance the state-of-the-art with conventional gyroscopes so that a commitment is necessary to go to non-conventional gyroscopes for further improvement in this type of device.